# THE ACID-BASE BALANCE OF THE BODY \*

#### Its Relation to Health and Disease

The Acid-Base Balance of the Body.—Until recent years little consideration was given to the question of the acidity or alkalinity of body fluids. But of late the importance of maintaining or restoring the acid-base balance in the prevention and treatment of disease has become a major problem of physiological and clinical research.

Progress in this direction has been so rapid that a new field may be said to have opened to the clinician, based on a greater knowledge of the chemistry of the body.

In this connection certain terminology has been inherited by us from our misinformed ancestors and a number of new terms has arisen to meet the newer knowledge. Some confusion has naturally followed, to overcome which it is necessary to become familiar with new words and phrases as well as to understand more thoroughly the action of salts, bases and acids in health and disease.

Terminology.—The body consists essentially of proteins, fats, carbohydrates, inorganic salts, carbon dioxide and water—the latter constituting at least 75 per cent of the total body weight (1). The percentage of any class of constituents in the body is fairly constant at all times.

Electrolytes and Ions.—It has been found that many inorganic salts, bases and acids in solution are capable of transmitting an electric current. Such substances are termed "electrolytes."

This ability to carry an electrical current is satisfactorily explained by the Ionic Theory, which hypothesizes that in a solution of electrolytes a process of dissociation takes place, the molecule being broken down into ions, one class of ions carrying a positive charge and other ions carrying a negative charge of electricity. Thus in the case of sodium chloride, for example, there would be present in the solution:

- (a) sodium chloride molecules, carrying no charge;
- (b) sodium ions, carrying a positive charge;
- (c) chloride ions, carrying a negative charge.

Acids and Bases.—The behavior of acids, bases and salts in water solutions is due to the activities of their ions. In this connection, two types of ion are especially involved, namely hydrogen ion and hydroxyl ion. If the hydrogen ions are in excess of the hydroxyl ions, a solution is acid; if fewer, the solution is alkaline.

Dissociation.—Some acids and bases are spoken of as "strong," while others are described as "weak." The essential difference lies in the degree of dissociation into ions. Each substance has a "dissociation constant," which differs with the individual substance. This means that not all substances in solution divide into their respective ions to the same degree.

For example, in an acetic acid solution, there are more of the combined hydrogen acetate molecules than there are of the hydrogen and acetate ions. Hence, acetic acid is a weak acid.

On the other hand, in a hydrochloric acid solution, more of the substance is in the form of hydrogen and

chloride ions than in the form of hydrogen chloride particles. This, then, is a strong acid.

What is pH?—Even distilled water breaks up slightly into its respective ions. The number of hydrogen ions here equals 0.0000001 grams per liter. This is expressed in terms of the power of ten, thus:  $[H+]=10^{-7}$ . Likewise, the hydroxyl ions also equal 1

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gram-molecules per liter, or, [OH-]=10-7. In other words, the two opposing ions balance, and the solution is neutral.

In view of the large figures involved, and the resultant confusion, Sörenson has introduced the term pH to simplify the nomenclature. By this method, the ten and the minus sign are omitted, leaving only the exponent. Thus, water has a pH of 7.

The total dissociation is always  $10^{-14}$ . Therefore, as the hydrogen ions increase, the hydroxyl ions decrease proportionately. For this reason, we are able to omit consideration of the hydroxyl ions and mention only the hydrogen ion concentration, remembering that the total is always 14. The pH, therefore, is based only on the hydrogen ion concentration.

To summarize, a pH of greater than 7 is alkaline, or basic, while a pH of less than 7 is acid. The farther away from 7, the more acid or alkaline.

pH of the Body Fuilds.—Normally, the pH of the blood is confined within the limits of 7.3 and 7.5. The maximum range of toleration, however, is between 7.0 and 7.8 (1).

Acidosis and Alkalosis.—The body fluids, therefore, are always slightly alkaline. A pH of 7.5 or over is called an "alkalosis" or "hyperalkalinity," while a pH less than 7.3 is variously termed "acidosis," "hyperacidity," or "hypoalkalinity." While the latter term more correctly defines the condition, "acidosis" is more popular in the literature and is most widely used by clinicians. For this reason we shall confine ourselves to the terms "alkalosis" and "acidosis," remembering that at no time does the blood give an acid reaction.

Buffer Salts.—The manner in which the body fluids are kept physiologically neutral is of great interest and importance. Briefly, this is accomplished in three ways: by the action of buffers, or tampons (those compounds that resist changes in pH when an acid or alkali is added); by respiration; and by excretion (4). We are particularly interested in the buffer salts of the body, which are comprised of both organic and inorganic substances (3).

The principal organic buffers are the proteins, which, because of their amphoteric properties, combine equally well with acids or bases. The dual character of this type of buffer is due to the protein molecule, which contains both amino (NH<sub>2</sub>) and carboxyl (COOH) groups. The amino group functions as an alkali and combines with acids, whereas the carboxyl group assumes acidic properties and combines with bases.

Graphically, the actions of the various types of inorganic buffer may be shown in the form of chemical equations, as follows:

#### 1. Bicarbonates

$$\begin{array}{c} \text{Na H CO}_3 \leftrightarrows \text{NA}^+ + \text{H CO}_3^- \text{ (An extremely weak acid)} \\ + & + \\ \text{H Cl} \leftrightarrows \text{Cl}^- + \text{H}^+ \\ \downarrow & \downarrow \\ \text{H}_2 \text{CO}_3 \\ \text{Na Cl} & \downarrow \\ \text{(Excreted by Kidneys)} & \text{H}_2 \text{O} + \text{CO}_2 \text{ (Excreted by Lungs)} \end{array}$$

This equation may be summarized as follows:

 $NA H CO_3 + HA (Any Acid) \rightarrow CO_2 + H_2 O + NA A$ (A Sodium Salt)

<sup>\*</sup>Editor's Note.—The National Institute of Health, successor to the Hygienic Laboratory of the United States Public Health Service, which in turn operates as one of the bureaus or divisions of the Treasury Department of the United States, came into existence through an act of Congress, approved May 26, 1930. One of the publications brought out by the National Institute is a small booklet on "The Acid-Base Balance of the Body." Part One of that booklet is here reprinted because it is more or less pertinent to the California Medical Association prize paper by Dr. Harold L. Thompson; which also appears in this issue under the title, "Resection of the Pylorus." (See page 383.)

#### 2. Carbonic Acid (Carbon Dioxide)

$$CO_2 + H_2O \Leftrightarrow H_2 CO_3 \Leftrightarrow H^+ + H CO_3^- + + +$$
 $N_A OH \Leftrightarrow OH^- + N_A^+ \downarrow \downarrow$ 
 $H_2 O N_A H CO_3$ 

This equation may be summarized as follows:  $NAOH + H_2CO_3 \rightarrow H_2O + NAHCO_3$ (An Alkali) (Carbonic Acid) (A much weaker Alkali than NAOH)

#### 3. Phosphates

In the presence of strong acids di-sodium phosphate combines with them to produce a weaker acid. By contrast in the presence of strong bases the blood supplies acid sodium phosphate to act as a buffer and produce by combination a weaker base.

Respiration.—The chief waste product of oxidation is carbon dioxide. This is carried as carbonic acid in the blood stream until it finally reaches the lungs and is released. The concentration of carbonic acid in the blood regulates the depth of breathing by stimulation of the respiratory center in the brain. Thus with increased acidity the breathing becomes faster and more carbon dioxide is released (hyperventilation) which in turn reduces the acidity to normal. An alkaline condition, on the other hand, results in diminished aeration and allows the acid (CO<sub>2</sub>) to accumulate in the body.

Excretion.—When the buffer salts and respiratory system are overtaxed by acid, the body rids itself of acid excess by way of the kidneys, the sudoriferous (sweat) glands, and the alimentary canal, the kidneys being the most important agent for this purpose.

The urine may become as acid as pH 5.0 or as alkaline as pH 8.0. This is due to the ability of the kidney to combine acids with the least amount of base in the presence of acidosis, and by contrast, to utilize the greatest combining power of acids in the presence of an alkalosis. The sweat glands act similarly to the kidneys.

In the case of the alimentary canal, Nature makes use of the urge to vomit in pathological cases as a means of keeping the digestive fluids normal in reaction. Also the normal fecal matter is found to contain certain electrolytes, indicating the function of the bowel in controlling the acidity of the body.

The Carbonic Acid-Bicarbonate Ratio.—Carbon dioxide may exist in the blood in four forms: free CO<sub>2</sub>, carbonic acid (H<sub>2</sub>CO<sub>3</sub>), bicarbonate (BHCO<sub>3</sub>), and carbonate (B<sub>2</sub>CO<sub>3</sub>), although actually only bicarbonate and carbonic acid occur in appreciable quantities (8). The two latter constitute the most important buffers of the body and upon their interrelationship depends to a great extent the acidity of the body.

When the ratio 
$$\frac{\text{NaHCO}_8}{\text{H}_2\text{CO}_8} = \frac{20}{1}$$
, the pH of the body

may be said to be 7.4 (Hartmann), other factors being unchanged. This ratio is considered normal. It would seem that such a fraction would tend toward alkalinity, but it must be remembered that blood serum is normally slightly alkaline and that weak acids require a large amount of alkali to alter their reaction to any given extent; carbon dioxide, for example, requires 24 times as much alkali as acetic acid to bring about a definite alteration (Stewart).

This peculiarity enables the body to possess a greater potential alkalinity than the titratable alkalinity. The bicarbonate is held in reserve by carbonic acid, but when alkali is needed, the carbonic acid is excreted in the form of CO<sub>2</sub> and the alkali released for utilization.

### HEALING CULT COSTS

Under the caption "Twelve Per Cent of Medical Cost Paid Annually to Healing Cults," the United States Daily of May 2, 1932, printed the article reproduced below. The article deals with a recent report of the Committee on Costs of Medical Care, and the facts contained therein should be of interest to all citizens. It is to be regretted that our American lawmakers have never seemed to recognize the importance of laying down proper minimum standards of preliminary and professional education and training, applicable alike to all persons seeking legal sanction to practice the healing art, be that practice of nonsectarian (regular) or of sectarian (cultist) form. This subject of basic qualifications is also discussed elsewhere in this number of California and Western MEDICINE (see report of special committee on "Qualifying Certificate" Act and Medical Practice Law, page 446).

The article from the United States Daily follows:

## TWELVE PER CENT OF MEDICAL COST PAID ANNUALLY TO HEALING CULTS

Legislation in the United States fails to protect the public against unqualified and poorly trained practitioners of various healing cults who are receiving \$125,000,000 annually for their services, the Committee on the Cost of Medical Care announced in a statement received by the Department of the Interior April 30. This sum represents 12 per cent of the annual American medical bill.

The statement, which summarizes the report of Louis S. Reed presented to the committee, says that although states maintain high standards for doctors of medicine, legislation "sanctions the existence on a lower plane of qualifications of thousands of poorly trained practitioners." The use of any therapeutic measures by unqualified persons, the statement points out, is "unsound, dangerous and wasteful."

It is recommended that laws require healing practitioners who apply for licenses to practice their art first pass an examination of the basic sciences, be properly trained, and possess an adequate knowledge of the human body and diseases. One of the reasons that people apply to this group is because many are still "basically superstitious" about disease and health and regard medicine as "magic." The statement of the committee, of which Dr. Ray Lyman Wilbur, Secretary of the Interior, is chairman, follows in full text:

Approximately \$125,000,000 annually, equivalent to 12 per cent of the amount spent on the 142,000 doctors of medicine, is expended in the United States on 36,150 other practitioners who hold themselves out to treat the sick—osteopaths, chiropractors, naturopaths and allied healers, and Christian Science and New Thought practitioners—according to Louis S. Reed, Ph. D., in a report presented May 1 to the Committee on the Costs of Medical Care.

Present legislation designed to protect the public from unqualified practitioners is not accomplishing its purpose, according to the report, for, although it maintains high standards for doctors of medicine, it sanctions the existence on a lower plane of qualifications of thousands of poorly trained practitioners. The use of any therapeutic measures by untrained or poorly trained individuals, unable to diagnose disease and unaware of their limitations, is unsound, dangerous and wasteful, no matter how sound those measures may be, Mr. Reed said.

The report stated that, while religious healing is able to accomplish beneficial results in some conditions, it may be harmful when practiced by those unable to diagnose disease, especially when it is held that disease is an illusion.

Mr. Reed's report, "The Healing Cults," published by the University of Chicago Press, is the sixteenth study completed by the Committee on the Costs of Medical Care, which, on November 29, will issue its final report with recommendations based on its exhaustive five-year study of the problem of "the delivery of adequate, scientific medical service to all the people, rich and poor, at a cost which can be reasonably met by them in their respective stations in life."

As a result of his exhaustive study, Mr. Reed estimated that the people of the United States annually spend \$42,000,000 for the services of the nation's 7,650 osteopaths; \$63,000,000 on 16,000 chiropractors; \$10,000,000 on